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ABSTRACT

Research on this National Science Foundation grant to study the application of modern communications technology to educational networking was divided into three parts: assessment of the role of technology in non-traditional post-secondary education; assessment of communications technologies and educational services of current or potential future use in educational networks; and synthesis of educational networks. This final report focuses on work completed from July 1, 1974 to April 30, 1975. Four studies of technology in non-traditional higher education, two studies of communication technologies in educational networks, and two studies of synthesis of educational networks are summarized. The report is followed by a list of publications, reports, and theses. (CH)

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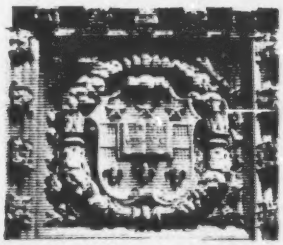

WASHINGTON UNIVERSITY

FINAL TECHNICAL REPORT

PROJECT ON
APPLICATION OF MODERN COMMUNICATION TECHNOLOGIES
TO EDUCATIONAL NETWORKING

NSF GRANT NO. EC-38871

SUBMITTED BY

ROBERT P. MORGAN, PRINCIPAL INVESTIGATOR
LESTER F. EASTWOOD, JR., PRINCIPAL INVESTIGATOR

CENTER FOR DEVELOPMENT TECHNOLOGY
WASHINGTON UNIVERSITY

GRANT DURATION

MAY 1, 1973 - APRIL 30, 1975

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Robert P. Morgan and Lester F. Eastwood, Jr., Principal Investigators

Grant Duration From May 1, 1973-April 30, 1975

A. PROJECT OBJECTIVES AND PLAN OF ATTACK

On May 1, 1973, the Center for Development Technology, Washington University, received a grant of $122,000 from the National Science Foundation to carry out an interdisciplinary research project on Application of Modern Communications Technologies to Educational Networking. A major goal of this research effort was to perform analyses which will prove useful to individuals concerned with the future role and development of educational networks involving technology and telecommunications, particularly at the post-secondary level. Such individuals include educators, government planners and policymakers, educational administrators and students, and the public at large. Networking can be accomplished with the aid of a variety of technologies, including cable, optical fibers, communications satellites, specialized microwave common carriers, and mailing of video cassettes to provide educational services which include television, computer-aided instruction, and information resource sharing.

The overall research effort was divided into three parts, the objectives of which were as follows:

1. Assessment of the Role of Technology in Non-Traditional Post-Secondary Education. This assessment included surveying existing and planned uses of technology in non-traditional, post-secondary education to determine technological configurations and costs of various technology-

based delivery systems, opportunities and plans for future technology utilization, and factors working for and against such utilization.

2. Assessment of Communications Technologies and Educational Services of Current or Potential Future Use in Educational Networks. Studies focussed upon a variety of technologies including bi-directional cable, fiber-optic communications, UHF radio broadcast, and the telephone system. Of primary interest were investigations of capabilities and costs, and trade-offs between transmission technologies, storage technologies and terminal devices.

3. Synthesis of Educational Networks. To illustrate a range of opportunities for technology utilization at various investment levels, this phase of the project synthesized a small number of hypothetical yet realistic educational networks. One study designed and evaluated a two-way, dedicated cable TV network to deliver a wide range of educational services to institutions in St. Louis. A second project considered alternative schemes for the delivery of PLATO-IV CAI.

The project was undertaken by a team of faculty, students and staff members representing a wide variety of disciplines relevant to the study. Table 1 lists the program participants. A list of papers, reports and theses completed or in preparation is included in Section C.

B. PROJECT RESULTS

1. Introduction

Progress has been made in all of the three primary research categories. First year progress of the project was reported in the Annual Technical Report covering the period from May 1, 1973 through June 30, 1974. The reader is referred to that report for details. In this final report, emphasis is placed upon accomplishment during the period from July 1, 1974

TABLE 1

PROGRAM PARTICIPANTS*

RICHARD J. BALLARD
Graduate Research Assistant, Electrical Engineering

WILLIAM S. C. CHANG
Professor of Electrical Engineering and
Director, Laboratory of Applied Electronic Sciences

LESTER F. EASTWOOD, JR. (Co-Principal Investigator)
Associate Director for Communications, Center for
Development Technology

VINCENT H. LI
Graduate Research Assistant, Electrical Engineering

ROGER L. McCLUNG
Graduate Research Assistant, Economics

ROBERT P. MORGAN (Co-Principal Investigator)
Director, Center for Development Technology and
Chairman, Program in Technology and Human Affairs

ROBERT E. MORLEY
Graduate Research Assistant, Electrical Engineering

DONNA L. ROTHENBERG
Research Analyst, Educational Technology
Center for Development Technology

JAI P. SINGH** (Co-Principal Investigator)
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MIKE D. WONG
Graduate Research Assistant, Program in
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OTHER FACULTY ASSOCIATES

BARRY D. ANDERSON, Ph.D.
Associate Professor of Education, and
Director, Graduate Institute of Education

NICHOLAS J. DEMERATH, Ph.D.
Professor of Sociology

EDWARD GREENBERG, Ph.D.
Professor of Economics

FRED J. ROSENBAUM, Ph.D.
Professor of Electrical Engineering

ARTHUR G. WIRTH, Ph.D.
Professor of Education

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*Includes only individuals who have received some support from current NSF grant since May 1, 1973.

**Now with the Indian Space Research Organization.

through April 30, 1975.

In general, the research effort has conformed to the original plan and objectives. Post-secondary education has been emphasized in view of strong current interest in activities such as the Open University (Great Britain), TICCIT and PLATO demonstrations directed at the community college level, SUN Project (Nebraska), regional computing activity, continuing engineering education via television, etc.

In the description of progress and results to follow, we have included descriptions of work performed at our Center germane to the NSF study which may have been supported in part by other sources. In these latter instances, sources of support are identified.

2. Assessment of the Role of Technology in Non-Traditional, Post Secondary Education

a. The Role of Technology in Non-Traditional, Higher Education

A study was completed by M. Wong under the supervision of R. P. Morgan on the role of technology in non-traditional, post-secondary education. This study brings together information on technology utilization and costs associated with current programs in this educational sector, and it uses this information to perform analyses and reach conclusions concerning future developments. To obtain the necessary information, extensive correspondence was carried out with a large number of institutions known to be involved in non-traditional, post-secondary education. The results of a questionnaire carried out in connection with the work of the Commission for Non-Traditional Study on technology utilization in colleges and universities were obtained from Educational Testing Service and provided a limited amount of information pertinent to our investigation. A questionnaire designed by Mr. Wong provided

additional information on technology utilization, costs and future plans of selected institutions as did a trip by Mr. Wong to the University of Illinois, Chicago Circle in connection with a visit by the Vice Chancellor of the Open University, Great Britain. This study, which constitutes Mr. Wong's M.S. thesis in the Interdepartmental Program in Technology and Human Affairs, was completed in August, 1974.

Mr. Wong found that technology-based networks are beginning to emerge as an important factor in higher education, particularly for off-campus delivery of televised instruction by large state university systems to satellite campuses or industrial locations. Factors working for and against utilization are explored as are system costs. Lack of funds is the foremost problem facing such networks. Developing a diversified user base can help provide the necessary financial base. At the time of the survey, respondents seemed confident that the future of technology-based networks was secure. More than half anticipated future growth and expansion. There was considerable interest in involvement in expanded networking and resource-sharing.

b. Large-Scale Educational Telecommunications Systems: An Analysis of Educational Needs and Technological Opportunities

In April 1975, a study was completed entitled "Large-Scale Educational Telecommunications Systems in the U.S.: An Analysis of Educational Needs and Technological Opportunities" by R. P. Morgan, J. P. Singer, D. Rothenberg and B. Robinson. This study was primarily supported by NASA grant funds. However, incorporated into the report were the results of the study of the role of technology in non-traditional, higher education discussed above and of a study of continuing professional education by Rothenberg which were supported under this NSF grant.

The Morgan, et. al. report examines in considerable detail the status of and trends and issues in a variety of educational subsectors. It explores current uses of technology and telecommunications in these subsectors, analyzing factors working for and against expanded utilization. It forecasts and identifies opportunities for future use of large-scale telecommunications systems in education. Post-secondary education is probably one of the more promising areas for large-scale telecommunications technology development.

c. Continuing Professional Education: Status, Trends, Issues and Prospects for Electronic Delivery

A study has essentially been completed by D. Rothenberg of the field of continuing professional education, with emphasis on status, trends, issues and prospects for electronic delivery. The professions examined were teaching, medicine, law and engineering. Public undertakings in the medical field include the computerized MEDLINE service of the National Library of Medicine, the WAT-21 Medical Television Network covering the State of Indiana, and the NASA-HEW ATS-satellite series health related experiments. Private enterprise efforts include the LEXIS computer-assisted research system for the legal profession and electronic "journals" published on videocassette by Visual Information Service for hospital subscription.

All the professions studied are in varying stages of commitment to, and experimentation with, electronic delivery systems for continuing education. More extensive adoption may hinge upon factors such as relicensure and recertification requirements, cost-effectiveness and the configuration of the technology, and the extent to which practitioners are able to pay for the services. The final study report should be completed

by the end of May, 1975.

d. Educational Production Functions and Alternative Technologies For Non-Traditional, Post-Secondary Education

NSF grant funds are partially supporting research initiated by R. McClung on Educational Production Functions and Evaluation of Alternative Technologies, with emphasis on non-traditional post-secondary education. The research constitutes Mr. McClung's Ph.D. dissertation in the Department of Economics under the supervision of Prof. E. Greenberg. A major goal of the research has been to compare the cost-effectiveness of television and computerized instruction with traditional methods in the delivery of post-secondary educational material to students. Mr. McClung's research concerns included the impact of technology on efficiency in education and the implicit policy implications as well as a comparison of the labor requirements for each technology.

Educational production functions have been developed relating educational outputs to inputs for several different methods of teaching one college level subject, namely accounting. Data were collected from Colorado State University, where accounting is taught by prerecorded television cassette; from the University of Illinois at Urbana, where the PLATO IV CAI system was used; and from the University of Missouri of St. Louis, which represented traditional instruction. As an output measure, the faculty at the three schools agreed to a common accounting exam which was administered as part of the final at two of the schools and as a series of quizzes at the third. Information on student and school inputs to the education process were collected on a student questionnaire as well as selected information from student files, using well defined procedures to ensure privacy.

Initial observations, albeit tentative, indicate that over one-fourth of a student's performance in accounting can be explained if we know his or her SAT scores, school, and the technology used. Other factors were less significant. Data analysis is continuing and policy implications remain to be examined. It is expected that Mr. McClung's dissertation will be completed during the summer of 1975.

3. Assessment of Communications Technologies and Educational Services of Current or Potential Future Use in Educational Networks

a. Introduction

The delivery of educational information requires a cost-effective method for transmitting data point-to-point, and it demands an effective distribution network to provide easy access to users. One or more of the various broadband communication technologies -- cable networks, microwave relay links, satellite relay, and fiber optics, for example -- may meet both of these requirements. We have undertaken investigations to study the properties of these technologies and, in addition, to assess existing broadband communication networks such as urban cable systems, communications satellites, and ITFS and other microwave relay links.

Technological factors influenced the system configurations we proposed. Network economics and performance depended strongly on the costs and capabilities of the transmission media, display devices, and storage devices incorporated in the interconnection. In addition, the services which the network supplied determined features of the delivery system. For example, computer-aided instruction, interactive television, and broadcast lectures each required a different level of sophistication in the communication systems which deliver them. Because of their

importance to the goal of this program, we mounted a major study effort to investigate technical topics relevant to educational networking.

b. Technical Parameters and Costs of Educational Communications Technology

Professor Eastwood and Mr. Richard Ballard, a master's candidate in Electrical Engineering, have reviewed the technical parameters which are important in the design of existing delivery systems for education. Included in this investigation were broadcast educational radio and television, film and videocassettes, remote classrooms over closed circuit and microwave links, computer-based instruction, and remote document access systems. Examples of these technology-based educational systems were systematically studied to discover parameters important in future system designs. This work resulted in a technical report, issued by our Center, entitled "Telecommunications Media for the Delivery of Educational Programming." The report listed typical studio production equipment necessary for broadcast radio and TV, and gave cost ranges for equipment of various performance levels. Transmitter equipment and home receiver units were similarly analyzed. Technical limitations (for example, allowable signal to noise ratio or broadcast coverage area as a function of transmitter power and antenna height) as well as legal limitations (FCC regulations, channel allotments, etc.) determine network design; therefore they were carefully studied. In a similar manner, the report analyzed remote and interactive TV classrooms, videocassettes, the PLATO-IV and TICCIT CAI systems, and the INTREX and New York Times systems for remote access of documents.

Copies of this report have been in strong demand since its issuance by planners of telecommunications networks. For example, the Educational

Telecommunications Advisory Council of the Michigan State Board of Education has ordered twenty-five copies. In addition. the editors of Educational Technology Systems found the analysis of the costs and performance of the PLATO IV CAI system contained in the report of interest, and asked us to submit it for publication in their journal. The resulting paper, "The PLATO-IV CAI System: Where Is It Now? Where Can It Go?," will soon be published. The paper critically analyzes PLATO's performance and costs, it identifies areas in which cost improvements must be made -- the communications network, the programming production method, and the student terminal -- before the PLATO system can be a viable operational, rather than experimental, entity.

The Ballard and Eastwood research has also investigated the costs and capabilities of CATV technology in detail. This work will be described in the "Synthesis of Educational Networks" section below.

c. The Role of Fiber Optics Technology in Educational Networking

Prof. W.S.C. Chang and graduate student Vincent Li of Electrical Engineering have investigated the state-of-the-art of fiber optics communication technology, a developing potential competitor of cable technology in wideband, community telecommunications networks. A result of this work, a technical report entitled "Fiber Optics Communication Technology for Educational Communications," reviews the fiber's present capabilities and costs and attempts to foresee problems in the development of the technology as a viable alternative to cable.

The report describes several attractive features of optical communications through fibers which may result in its increasing adoption over the next few decades. THis technology offers the potential of extremely large information-carrying capacity, small cross-section, easy to install

transmission lines, freedom from electromagnetic interference, low attenuation of signals with distance, and low cost. Which of these potential benefits will be realized depends on the successful development of various components now in the experimental stage. For example, costs may not become attractive if the price of low-loss fiber transmission cables does not continue its present downward trend.

Development of major components for fiber optics is proceeding rapidly. However, present research efforts have been concerned almost exclusively with point-to-point transmission; very little is presently known about possible configurations of fiber networks. Since our interest in the broadband communications technologies is in their use in networks, the goal of our fiber research has been to build the capability to propose and assess fiber optics networks designs.

Mr. Li's master's thesis, which is scheduled for completion in May, 1975, contains a method for evaluating the probability of error performance of a point-to-point fiber communications link in addition to the information described above.

4. Synthesis of Educational Networks

a. A Two-Way Cable Television Network Dedicated to Institutional Use for St. Louis

In the network synthesis phase of their study, Prof. Eastwood and graduate student Richard Ballard proposed and evaluated a set of alternative designs for an interactive, cable television network for the colleges, hospitals, and major industries in the St. Louis area. After an intensive study of cable television technology, they proposed a geographic layout and alternative hardware configurations for the network and made detailed estimates of the purchase, installation, and maintenance costs for each resulting network design. In addition, using the information developed

in their earlier report on the costs and communications requirements for educational services deliverable by a communications network, they specified the equipment and number of cable channels in the network necessary to deliver these services. These results permitted a per-user contact-hour cost calculation for each service. In addition to producing realistic network designs for St. Louis, the research has shown that, assuming relatively full utilization of the network's capacity, most of the services listed previously by Ballard and Eastwood (See 3b) could be delivered at a very low cost per user contact hour. The results of this work are summarized in a report to be completed by June of 1975. The work is also described in Mr. Ballard's master's thesis, which will be completed in May of 1975.

b. Alternative Communications Network Designs for the Delivery of PLATO-IV-Type Computer-Aided Instruction

The study just described considered the delivery of many educational services to an urban-suburban area; this study took a different approach. Undertaken by Prof. Eastwood and graduate student Robert Morley, this project analyzed alternative means of delivering a single service, computer-aided instruction, to areas of widely varying demography. The study was supported in part by NASA and in part by the NSF grant.

We designed networks to serve an operational PLATO-IV CAI system using three communications technologies: leased phone lines, communications satellites, and microwave or UHF radio broadcast. Basing our work on these designs, we calculated a communication cost per student contact hour for each delivery method and determined how the cost changed as the population density of the area served varied. Under the assumptions used, satellite delivery was cost optimum for sparsely populated areas; radio,

for moderately populated ones, and in densely populated locations, telephone was least expensive. These results, however, are sensitive to assumptions on how individual terminals are distributed. If terminals are grouped together at a community learning center, radio may be more attractive than telephone, while if they are scattered at individual sites, telephone may be superior in a given situation.

It is also of interest to note that the communications cost figures calculated for these optimum network designs are far lower than those borne by most users of the existing PLATO system. Results of this work will appear in a technical report to be produced by June, 1975. The results are also described in Mr. Morley's thesis, due for completion in May, 1975.

C. LIST OF REPORTS, PUBLICATIONS, THESES*

1. Completed

Ballard, R. and L. F. Eastwood, Jr., "Telecommunications Media for the Delivery of Educational Programming," Center for Development Technology Memorandum No. 74/1, Washington University, (143 pp.), November 1974. (ERIC No. ED 100349**)

Eastwood, Margaret A. and Lester F. Eastwood, Jr., "A Software Implementation of a Satellite Interface Message Processor," Center for Development Technology Memorandum No. 74/2, Washington University, (59 pp), December 1974. (ERIC No. ED 100347)**

Eastwood, L. F. Jr., and R. Ballard, "The PLATO-IV CAI System: Where Is It Now? Where Can It Go?," accepted for publication in Educational Technology Systems.

Morgan, R. P., "Communications Technology in the Future of Higher Education in the United States," Symposium on Communications Media and the Future of Higher Education convened at the invitation of Dr. Henry R. Cassirer, Deutsche Verlags-Anstalt, Stuttgart, Germany, November 2-4, 1973. (ERIC No. ED 089 664)**

Morgan, R. P., Singh, J. P., Rothenberg, D. and B. E. Robinson, "Large-Scale Educational Telecommunications Systems for the U.S.: An Analysis of Educational Needs and Technological Opportunities," Center for Development Technology Memorandum No. 75/1, Washington University, (425 pp.), April, 1975. (Available from ERIC in near future)**

Wong, M. D., "The Role of Technology in Non-Traditional Higher Education," M.S. Thesis, Program in Technology and Human Affairs, Washington University, Center for Development Technology Report No. (R)T-74/3, Washington University, (307 pp.), August, 1974. (ERIC No. ED 094 760)**

2. In Preparation

a. Theses

Ballard, R., "Telecommunications Networks for the Delivery of Educational Programming," M.S. Thesis, Department of Electrical Engineering, Washington University, St. Louis. (Scheduled for completion May 1975)

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Li, V., "Fiber Optics Technology for Educational Applications," M.S. Thesis, Department of Electrical Engineering, Washington University, St. Louis. (Scheduled for completion June 1975).

McClung, R., "Educational Production Functions for Non-Traditional, Post-Secondary Education," Ph.D. Thesis, Department of Economics, Washington University, St. Louis. (Scheduled for completion Summer 1975).

Morley, R., "Alternative Delivery Networks for an Operational PLATO IV CAI System," M.S. Thesis, Department of Electrical Engineering, Washington University, St. Louis. (Scheduled for completion May 1975).

b. Reports and Publications

Ballard, R. and L. F. Eastwood, Jr., "A Dedicated Interactive Cable Television Network for St. Louis Institutions." (Scheduled for completion June 1975).

Eastwood, L. F. and R. E. Morley, "Broadcast Radio Delivery Techniques for Computer-Aided Instruction." (Scheduled for completion May 1975 for presentation at National Telecommunications Conference, New Orleans, LA.)

Eastwood, L. F. Jr. and R. E. Morley, "A Dedicated Communications Satellite for Delivery of Computer-Aided Instruction." (Scheduled for completion Summer 1975, for publication).

Li, V., "Fiber Optics Communication Technology for Educational Communications." (Scheduled for completion May 1975).

Morley, R. E. and L. F. Eastwood, Jr., "Networking Alternatives for the Delivery of an Operational CAI System." (Scheduled for completion June 1975)

Rothenberg, D., "Continuing Professional Education: Status, Trends, Issues and Prospects for Electronic Delivery." (Scheduled for completion May 1975).